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Production Scheduling at Falcon Die Casting: A Comprehensive Example on the Application of Linear Programming and Its Extensions

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Falcon Die Casting Company (FDC) is an automotive parts manufacturer based in Ohio. FDC recently patented an innovative method of high volume die casting using traditional die casting machines. This patent was instrumental in FDC receiving a long term contract from a major automobile manufacturer for the bulk of its requirements for five key die cast items used in most of its automobiles.

The customer provides FDC with an indication of the possible demand for the next 12 weeks with the understanding that demand beyond Week 2 is tentative and subject to change depending on auto sales during the preceding weeks. Table 1 shows the projected demand for the next 12 weeks.

FDC can produce the parts on five die casting machines, each of which is capable of producing a subset of the parts as indicated in Table 2. For example, Part 1 can be produced only on Machines 1 and 2. Similarly, Machine 4 can only produce Parts 2 and 3. While FDC has the design capacity needed to meet the customer's long term demand for the five parts, the effective capacity at present is just enough to satisfy the demand because a significant percentage of items produced are not at a quality level demanded by the customer. This situation is likely to remain the same for the immediate future until the defect levels are gradually brought under control through experience and continuous improvement. FDC's industrial engineers developed yield factors, which are quite accurate in predicting the proportion of parts that meet the customer quality specifications. Table 2 provides the production rates for the five parts on the five machines along with the yield factors. For instance, producing Part 1 on Machine 1 for 3 hours yields 72 ($= 3 \times 40 \times 0.6$) items of Part 1 that meet the specifications and, thus, can be used to fulfill demand. There is no wastage of metal because defective parts can be melted and reused.

Production takes place Monday through Friday with three eight-hour shifts per day, yielding 120 hours

Table 1 Projected Demand

Week	Part 1	Part 2	Part 3	Part 4	Part 5
1	3,500	3,000	4,000	4,000	2,800
2	3,000	2,800	4,000	4,300	2,800
3	3,000	2,000	4,000	3,500	3,000
4	3,000	3,000	4,000	3,800	2,800
5	3,000	3,000	4,000	4,000	2,800
6	3,500	2,500	4,000	3,800	2,500
7	3,500	2,500	3,800	4,000	2,500
8	3,300	3,400	3,700	4,200	2,500
9	3,300	3,400	0	4,500	3,000
10	3,200	3,000	0	4,500	3,000
11	4,500	4,000	5,000	5,000	3,800
12	3,000	2,800	4,000	4,300	2,800

Table 2 Production Rates (Units/Hour)

	Part 1	Part 2	Part 3	Part 4	Part 5
Machine 1	40			60	
Machine 2	35	25			
Machine 3		30			45
Machine 4		35	50		
Machine 5				60	50
Yield (%)	60	55	75	65	60

Table 3 **Part Setup Times (Hours)**

	Part 1	Part 2	Part 3	Part 4	Part 5
Machine 1	8			8	
Machine 2	10	8			
Machine 3		10			24
Machine 4		8	12		
Machine 5				8	20

of regular time per week on each machine. Weekends are normally used for preventive maintenance and experimentation to improve the production process but may be used for overtime production when necessary. Thus, the maximum possible overtime production on any machine is 48 hours per week. Based on the current projected demand for the five parts, FDC realized that overtime production over the weekends will be a fact of life until the yields are sufficiently improved. Due to a long standing policy of not keeping any finished goods inventory at the end of a week, weekly production is limited to that week's demand.

Setting up machines to produce various parts takes significant amount of machine time, ranging from 8 to 24 hours as shown in Table 3 and setup times do not depend on the order in which the parts are produced on a machine. Setup and production of a part can span more than one shift without any lost time. However, as a consequence of preventive maintenance and experimentation over the weekends, all machines need to be set up anew each week.

Weekly production planning is typically carried out in a time-consuming trial-and error-process by adjusting the previous week's production plan taking into account changes in the weekly demands, production rates, and setup times. While production planners do their best to avoid unnecessary setups, on many occasions production of a part had to be scheduled on more than one machine in order to meet the customer demand. Additionally, the final schedules often resulted in excessive overtime on some machines while other machines were idle during the regular time production.

Tom Kelley, the production manager, wanted scheduling to be carried out in a systematic manner with some assurance that the final schedule assigns production of parts to machines in an optimal manner. Since production employees are paid time and half for overtime work, Tom is very keen on meeting the demand for the five parts with the least amount of overtime.

Tom is also curious about the impact of the company policy to not carry finished-goods inventory from week to week. He has had discussions with the maintenance supervisor that lead him to believe that it should be possible to perform routine maintenance during weekends without disturbing the machine setups.

Suggested Questions

1. Using a trial and error approach, propose a production schedule for meeting the first week's demand for the five parts.
2. Develop a linear programming model to determine the optimum production schedule that minimizes the total machine hours of overtime needed to meet the weekly customer demand. Assume that the weekend preventive maintenance effectively resets the machines so that new setups are required to start production each week. Note that in this scenario any remaining production time that is insufficient to setup for a new part, is simply lost. This is a consequence of the maintenance process and the company policy of not carrying any inventory between weeks.
3. Whenever overtime production needs to be scheduled, the traditional practice has been to schedule it on machines that are most efficient for the part being produced. This has often led to uneven overtime assignment in the sense that long hours of overtimes are scheduled on one or two machines while other machines remained idle. While this resulted in lower total overtime paid to production personnel, it often resulted in higher overall costs because of the overtime costs of the required support personnel such as administrative assistants, electricians, material handlers and quality control technicians. Their presence is necessary as long as production is in process, irrespective of the number of machines operating. Tom

wondered if it would be more economical to schedule production on more machines over the weekend and minimize the total duration for which overtime production takes place. Modify your model to minimize the total duration of overtime production (i.e., maximum of the overtimes on all machines) rather than the sum of overtimes on all machines? Compare the optimal production schedule obtained with the new objective with that for question 1 and then discuss the nature of changes in the optimal solution.

4. Modify your model to minimize the total cost of overtime for production and support personnel, assuming that the cost of scheduling overtime on each machine is $30 per hour and the cost of support personnel during overtime is $40 per hour.

5. At present, the weekend preventive maintenance effectively resets the machines so that a new setup is required to start each week's production (question 1). Tom and the maintenance supervisor developed a method by which the routine maintenance can be performed without disturbing its setup. Modify your model to take advantage of the initial setup on a machine at the beginning of a week. Assume that machines 1 through 5 are setup to produce parts 1, 2, 5, 3 and 4 respectively, at the start of week 1.

Bonus scenarios:

6. The new maintenance method can also result in additional savings if production on any machine can be sequenced such that the machine ends a week's production setup for a part and starts the following week producing the same item. Extend your model to schedule production for two weeks at a time.

   FDC is strongly committed to being responsive to customer's needs and attempts to satisfy all demand by using overtime when necessary. On some occasions, weekly production requirements exceeded FDC's capacity, even with maximum overtime. Under these conditions, FDC believes that it is critical that these shortfalls are recognized early in the process and communicated to the customer as soon as possible with a clear indication of the likely delays in delivery.

   Tom noticed that during some weeks, while overtime is scheduled on some machines, other machines were not fully utilized during the regular time. Tom also noticed that in some weeks, more than one machine needed to be setup for some of the parts to meet the weekly demand. He wondered if these inefficiencies could be reduced or eliminated if FDC relaxes their long-term policy of not maintaining finished goods inventory. In that case, any excess capacity on a machine in a week can be used to produce additional units to meet the following week's demand. This may also lead to a reduction in the number of machines that need to be setup for a given part during a week.

   Use the delivery schedule for week 11 in Table 1 as the new demand in week 1 and assume that a penalty cost of $3 per week is imposed for each unit not delivered on time. Assume that the cost of carrying inventory is $2 per unit per week. Modify your two-week scheduling model to permit inventory to be carried between two weeks and generate information on potential shortfalls.